Gravity Profiles Across the San Jose Fault on the Cal Poly Pomona Campus: University Quad

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Contents

Abstract

The San Jose Fault runs through the San Gabriel basin in Southern California. Traces of the fault are believed to run through the campus of California State University Pomona. Several geotechnical investigations have been conducted in an attempt to locate and classify these traces, but the results have been conflicting. The disagreement in the literature about the fault type (left-lateral strike slip versus reverse) coupled with the uncertainty of the fault's location adds to the mystery of the San Jose Fault and what kind of a role it plays on the Cal Poly campus.

Two profiles across the campus were chosen to run gravity surveys, to determine whether lateral variations in rock density could be detected, corresponding to the proposed locations of the fault. The choice of sites of the gravity profiles were based on the traces of the San Jose Fault as mapped by the GeoCon geotechnical investigation in 2001 and practical considerations of accessibility and terrain. The surveys were conducted using a LaCoste and Romberg Gravimeter and total station surveying instrument. The gravity surveys conducted in the University Quad at Cal Poly Pomona yielded gravity anomalies that suggest the possible presence of a shallow reverse fault.

Introduction

The San Jose Fault runs 18km along an area east of the Los Angeles Basin and South of the San Gabriel Mountain Range. The fault runs through the San Gabriel Basin, and along the San Jose Hills. Figure 1 shows a large scale map of the San Gabriel Basin and location of the San Jose Fault from Yeats et al. (2004).

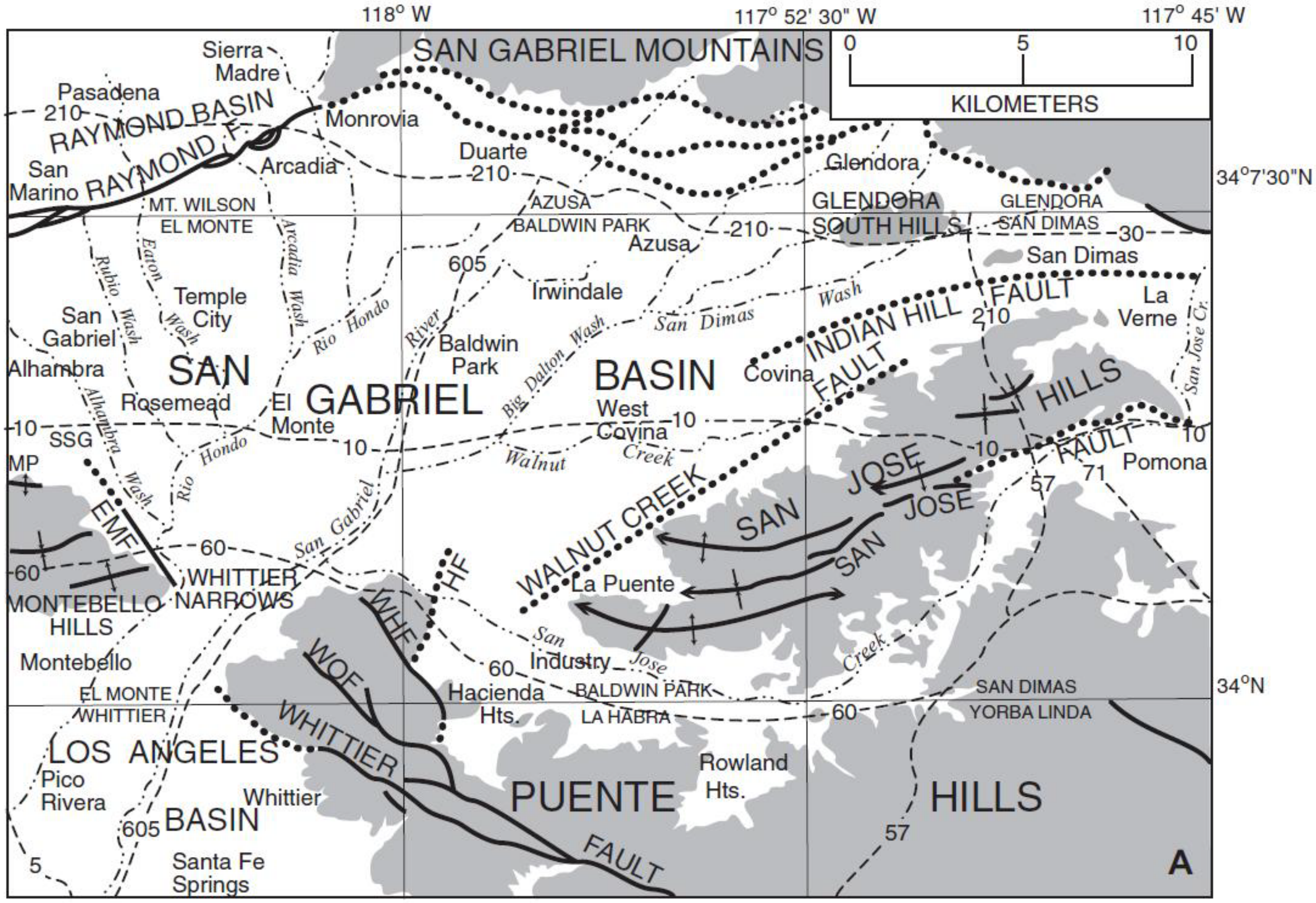


Figure 1: Overview map of San Gabriel Basin showing relative location of the San Jose Fault from *Tectonics of the San Gabriel Basin and Surroundings, Southern California.* Yeats et al (2004)

Traces of the San Jose Fault are thought to run directly through the campus of California State University Pomona in Pomona California. Disagreements arise as to what type of faulting the San Jose Fault represents, as well as the fault's activity and location. The Upland Earthquakes of 1988 and 1990 of magnitudes 4.6 and 5.2 respectively have been attributed to the San Jose fault by Hauksson and Jones (1991). Several geotechnical investigations have been conducted on campus in an attempt to locate and classify the fault traces; the most recent of which being a study conducted by GeoCon Inc. geotechnical group in 2001(GeoCon Inc, 2001). The zone for potential rupture or severe deformation along the central fault trace is approximately 150 feet wide on the hanging wall side of the fault and about 50 feet wide on the foot wall side. Through trenching, GeoCon Inc concluded that displacement of carbon dated alluvium beds occurred less than 3,500 years ago, and no evidence for more recent displacement has been interpreted by their investigation. (GeoCon Inc, 2001).

Motivation

The Seismic Review board has classified several buildings at CalPoly Pomona as some of the most seismically hazardous buildings in the entire CSU system (The Poly Post, 2011). The CSU board of trustees has recently voted to raze the iconic Classroom, Library, and Administration building due to poor construction and increased seismic concerns giving rise to more questions about the San Jose Fault and its role on the CalPoly Pomona campus (The Poly Post, 2010).

News of the planned destruction of the CLA building and the disagreements in the literature about the fault's characteristics and detailed locations serve as motivation for this experiment. The goal of this senior thesis research is to investigate whether a signal can be detected in gravity measurements that would correspond to the location of the fault traces as mapped in the GeoCon Inc. report.

Method

Gravity variations measured at the Earth's surface can be an indication of lateral density variations in the subsurface. Gravitational acceleration values are given by the equation $F = -G\frac{M}{r^2}$ where G=6.67x10^{-11}Nm^2/kg^2 , M is equal to the mass of the object, and r is equal to the distance between the object and reference point. Because gravitational acceleration is dependent on mass, M, more dense materials have a higher gravitational acceleration, making gravity useful for modeling the subsurface where there is a high density contrast between subsurface materials. Observed changes in gravitational acceleration are small relative to the overall gravitational attraction of the Earth and thus very precise measurements of relative gravitational acceleration are required. Modeling from gravity yields a non-unique solution. It is not possible to obtain a unique model by inverting measurements of gravity acceleration, so commonly a forward modeling approach is used.

A reverse fault presents a situation in which there may be a large density contrast in subsurface material; material which is more dense is brought up from depth on the hanging wall side of the fault. Thus, gravitational acceleration on the hanging wall side of the fault will be larger than gravitational acceleration measured on the footwall side of the fault. Conducting a gravity survey across a reverse fault yields a characteristic pattern of observed gravity when plotted on a graph against distance. An example of this characteristic profile for reverse faulting can be seen in Figure 2, a profile from *Implications for the Formation of the Hollywood Basin from Gravity Interpretations of the Northern Los Angeles Basin, California* published by the USGS in 2001 (Hildenbrand et al, 2001).

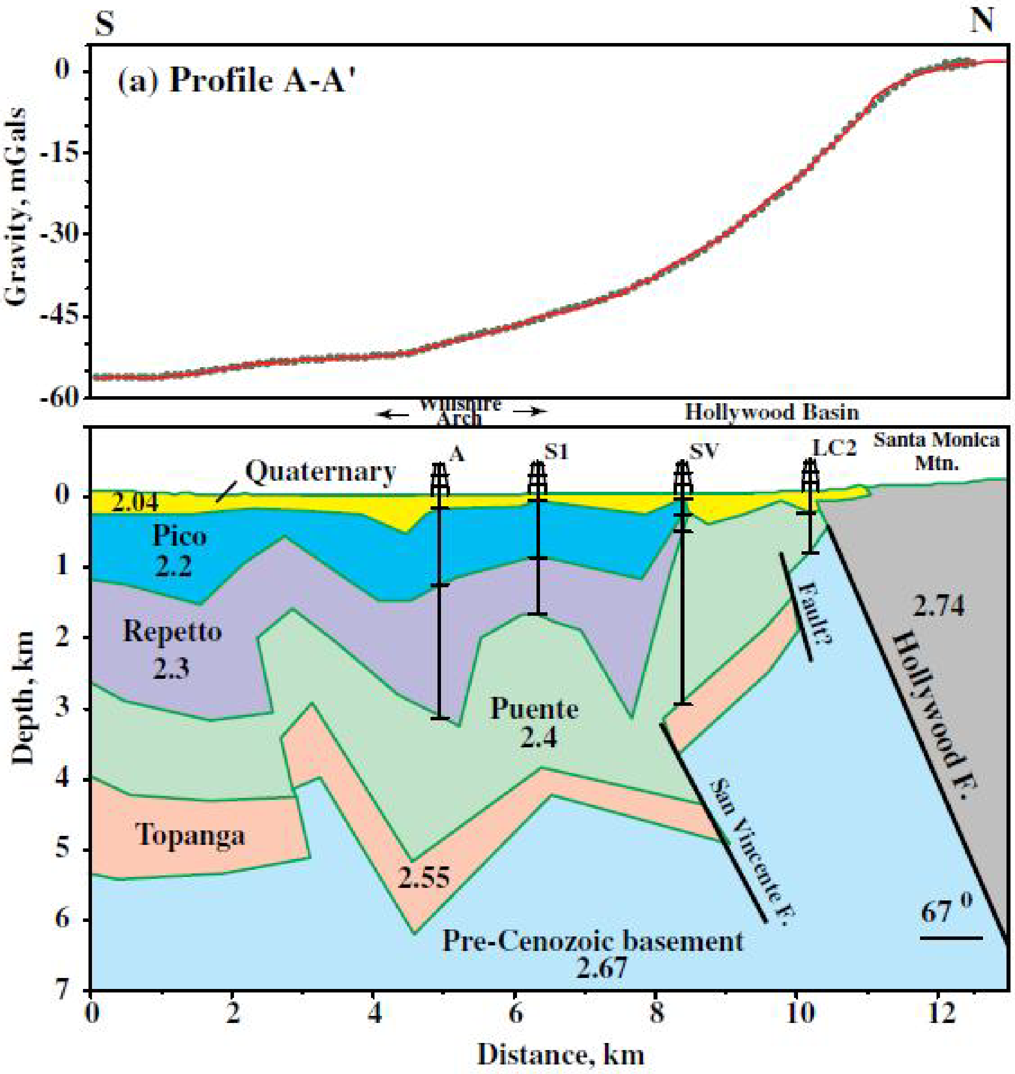


Figure 2: Gravity measurements across the Hollywood fault and density model (Hildenbrand et al, 2001)

In figure 2, gravity is plotted against distance across the Hollywood Fault. The gravity trend shown a steady increase in gravity values as the location moves closer to the hanging wall. The Santa Monica Mountains are on the hanging wall side of the fault which corresponds to higher gravity values.

Based on the San Jose fault traces as mapped by GeoCon, four locations on campus were selected to conduct gravity surveys. Figure 3 shows the Geocon map along with the locations of the gravity survey lines. Figure 4 shows a satellite image of the study area with locations of profile lines and fault traces. Profile lines 1 and 2, which cross through the main quad at CalPoly, will be discussed in detail in this report, profile lines 3 and 4 are discussed in detail in *Gravity Profiles Across the San Jose Fault on the Cal Poly Pomona Campus: Citrus Lane and Quad Profiles* (Potter, 2011).

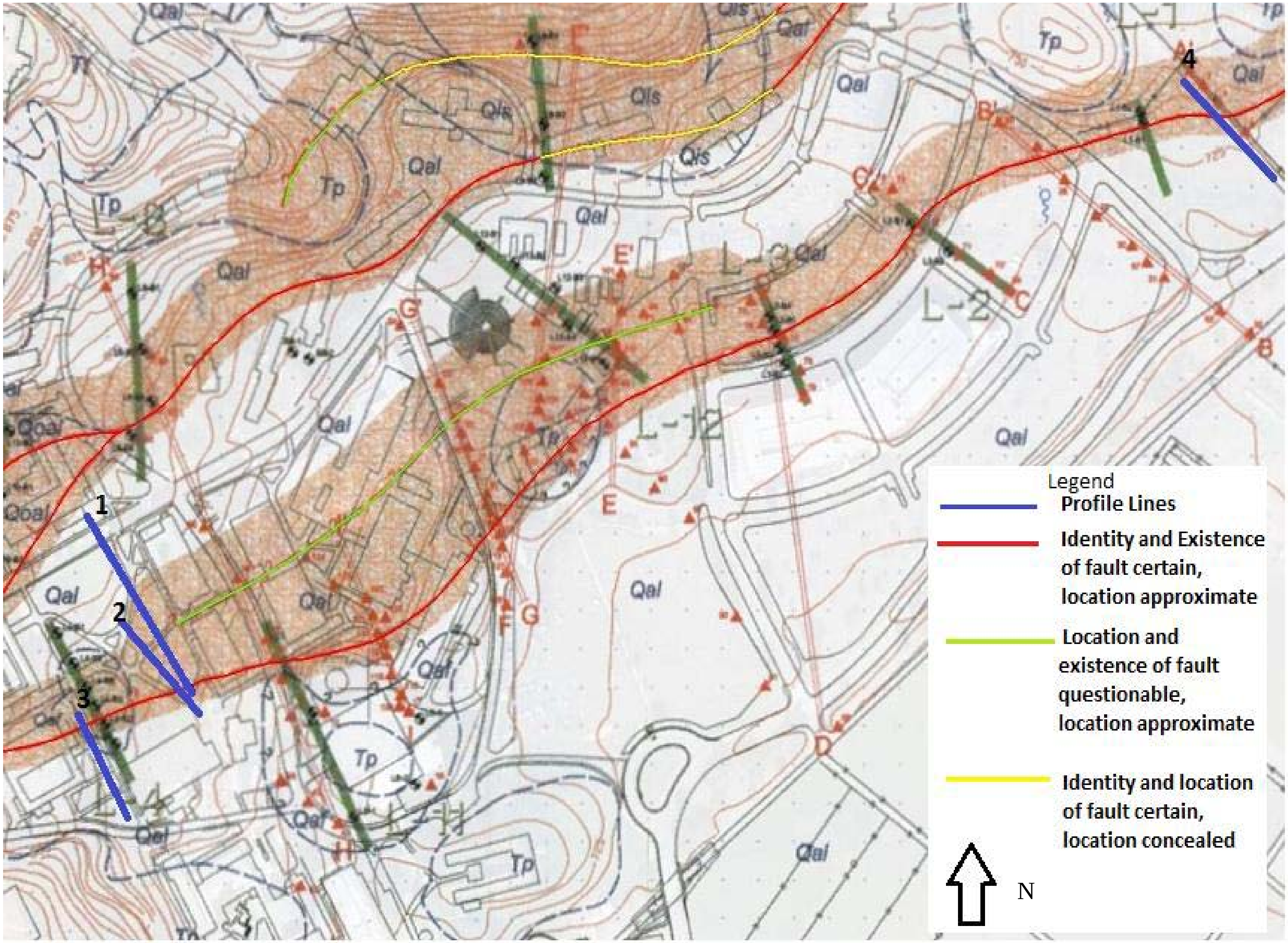


Figure 3: Map of California State Polytechnic University with fault traces and profile locations (adapted from GeoCon, 2001)

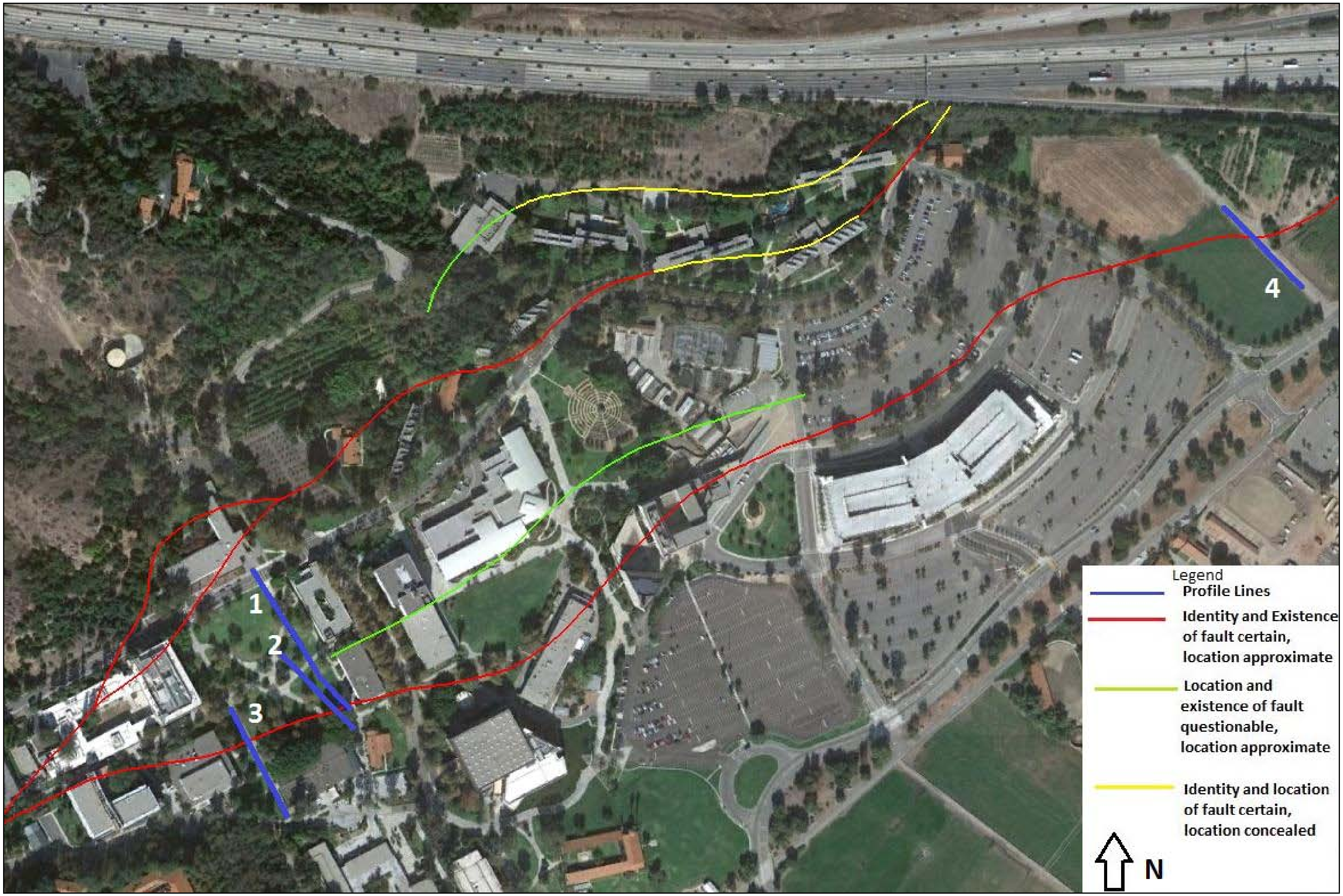


Figure 4: Satellite image of Cal Poly Pomona with fault traces and profile lines

Equipment

The equipment used to carry out the gravity survey consisted of:

-Garmin GPS

-Lacoste and Romberg Gravimeter

-Total Station

Gravimeter

A Lacoste and Romberg Gravimeter was used to measure gravity differences, relative to a designated base station, at equally spaced points along the profile line. The gravity meter is placed on a leveling plate to aid in the leveling of the device. Once the gravimeter is completely level, the damping knob can be turned releasing the mass and spring. Small amounts of force are either added or subtracted from the temperature controlled "Zero Length" spring, after which a series of levers restore the spring to the initial reading position, giving a precise gravity measurement (Fig. 5). The LaCoste and Romberg Gravity meter can obtain precision of 0.01mGal.

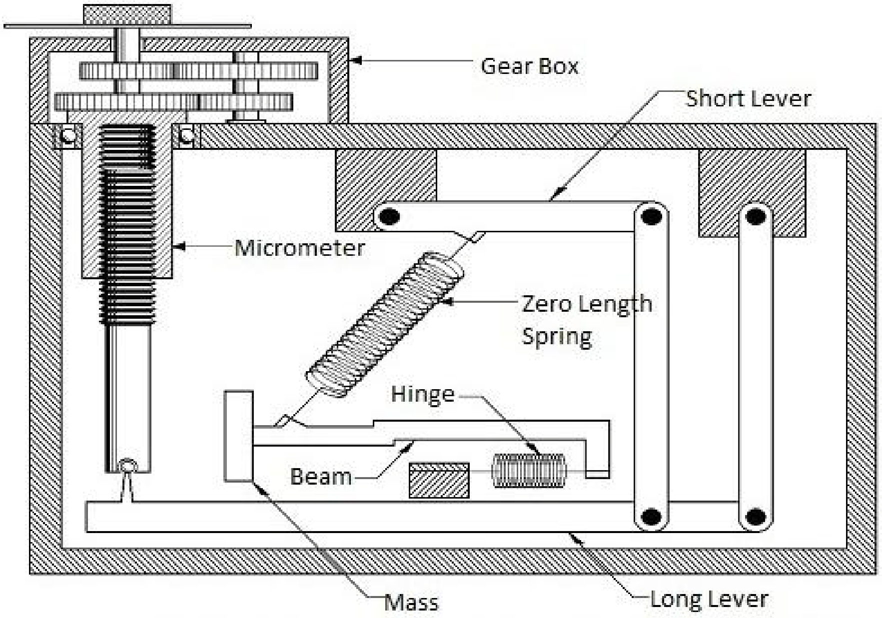


Figure 5: Interior components of a LaCoste and Romberg gravity meter from LaCoste and Romberg Instruction Manual for model D&G Gravity Meters 2004

Once the spring and mass have been released, the dial is turned changing the numbers on the counter (Fig. 6). The dial is turned until the lines seen through the eyepiece are completely centered. After the lines within the eyepiece are centered, the raw gravity measurement is given by the number displayed in the counter, and the dial. Raw gravity data taken from the gravity meter must first be converted into milligals. The conversion is done by calculations using values from LaCoste and Romberg calibration table (Appendix A). The calibration table is specific to the instrument.

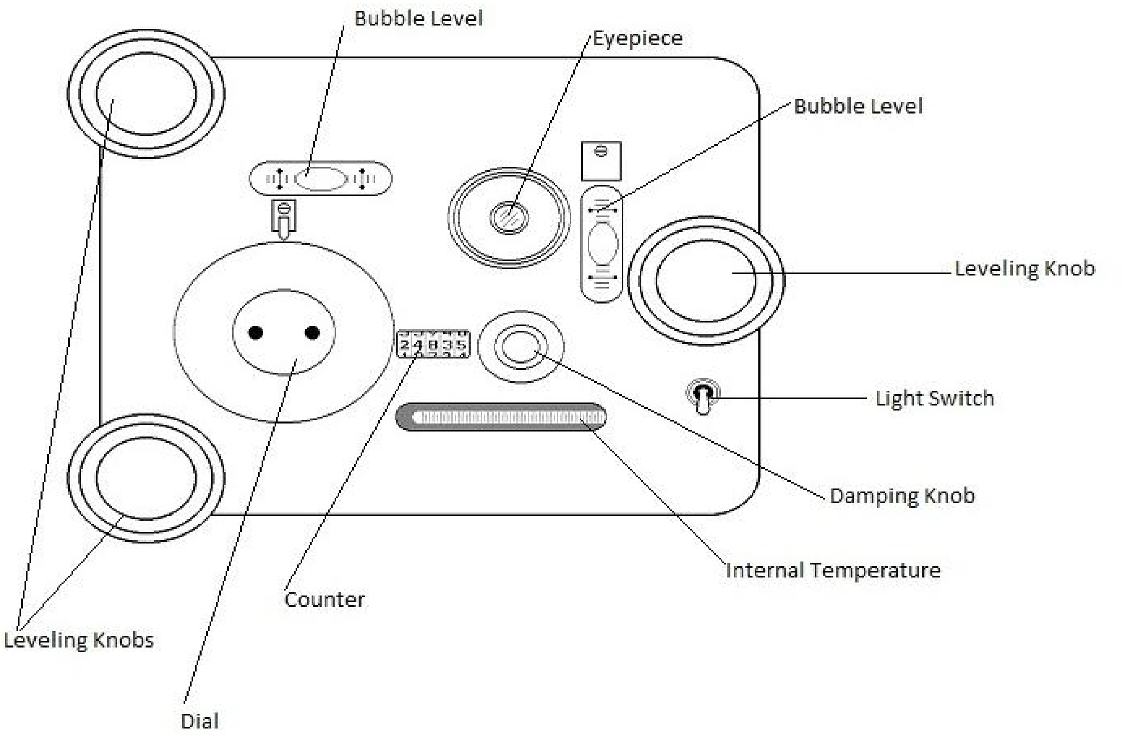


Figure 6: External Components of LaCoste and Romberg Gravity Meter from LaCoste and Romberg Instruction Manual for model D&G Gravity Meters 2004

Total Station

A Nikon Total Station was used to measure elevation at each of the gravity stations along the profile line. Because the gravity data given by the gravimeter must be processed and corrected, the elevation relative to the designated base station must be accurate. To assure an accuracy of 0.1mGal, elevation must be known to at least 33cm. The total station has elevation accuracy to a few millimeters, making it an important part of the gravity data collection and analysis.

Data

Processing and Corrections

In order to isolate a small gravity signal, many corrections must be made to the raw data. Initial gravity values given by the gravity meter must be converted into milligals. For the conversion, the calibration sheet for the gravimeter is used (Appendix A). Point 8 from appendix C will be used as a model point to demonstrate all corrections required to obtain a final gravity value.

Taking point 8 from appendix C, the gravity meter read 3127.99. On the calibration sheet (Appendix A), the highest value lower than the gravimeter reading is 3100. The “factor interval” is multiplied by the difference between measured value and tabulated value, and then added to the corresponding value in miligals. For point 8, this leads to:

$$[(3127.99-3100)\times 1.06046]+3284.64=3314.32mGal$$

Due to the spring’s extreme sensitivity to movement and temperature, gravity must be recorded at the base station several times throughout the course of the experiment. Gravity measurements are plotted versus time on a graph to determine whether or not the data should be adjusted for instrument drift. A linear correlation of gravity and time means that due to various reasons, the gravimeter has experienced drift, therefore the data collected should be corrected. If the instrument did not experience drift, then a drift correction is not necessary.

The gravity value in milligals must be further corrected in order to interpret the data in terms of subsurface structure. Gravity decreases with height above sea level, given by the gravity gradient, $g=GM/R^2$; thus the Free-Air correction must be made to the data. Because we are making relative measurements only, we can calculate free air corrections relative to the base station, which is assigned a 0 Free-Air correction value. The equation used to calculate the Free-Air correction is simplified to δ_{gFA}= -0.3086mGal/meter. For our example point, the vertical displacement of point 8 from the base station is 0.685 meters (Appendix C):

$$\delta g_{FA} = -0.3086 \times 0.685 = -0.2114\, mGal$$

Because point 8 is at a lower elevation than the base station, this value is then subtracted to the value of gravity in miligals to obtain the Free-Air anomaly:

$$-0.2114 + 3314.32 = 3314.11 mGal$$

Once the Free-Air anomaly has been determined, the Bouguer correction is then carried out. The Free-Air anomaly assumes no mass between datum and observation point, thus an additional correction must be made for mass: the Bouguer correction must be made. The Bouguer correction “adds” mass with some value of density to the Free-Air anomaly calculated previously. In this data, a density of 2.67g/cm^3 was used for rock density. Once again, the base station is set to a value of zero, making all other points relative to it. The Bouguer Correction equation is $\delta g_{Bouguer}=2\pi G\rho h$, where h is the elevation difference between the point of interest and the base station. A value of density of 2.67g/cm^3 is used. For our example point8:

$$\delta g_{Bouguer} = 0.04193 \times 2.67 \times 0.685 = 0.0767\, mGal$$

Because point 8 is at a lower elevation than the base station, the Bouguer Correction is added to the Free-Air anomaly to obtain the Bouguer Anomaly:

$$0.0767 + 3314.11 = 3314.87 mGal$$

The Bouguer Anomaly is the final value of gravity anomaly in miligals.

Gravity Profiles

After all data corrections were made for profile lines 1 and 2, Bouguer gravity anomaly was plotted versus distance. Figure 7 shows the gravity profile for location 1.

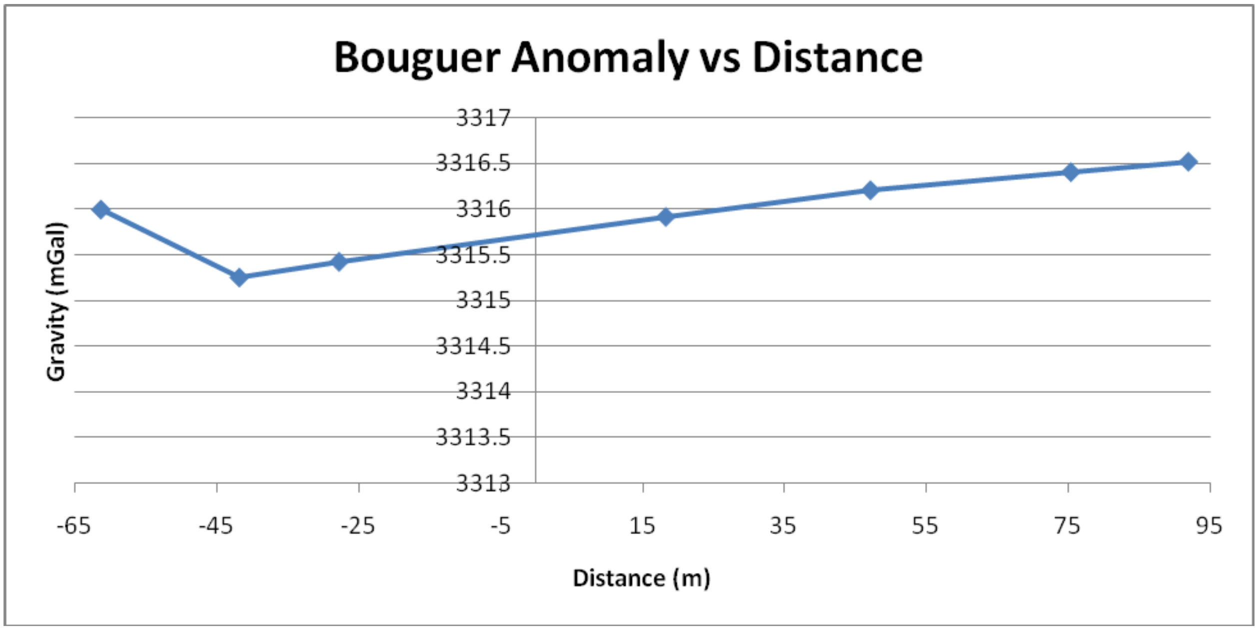


Figure 7: Gravity profile for line 1, extending from SE end of University Quad to Sidewalk in front building 1

Figure 8 shows the gravity profile for location 2, which is an extension of profile line 1.

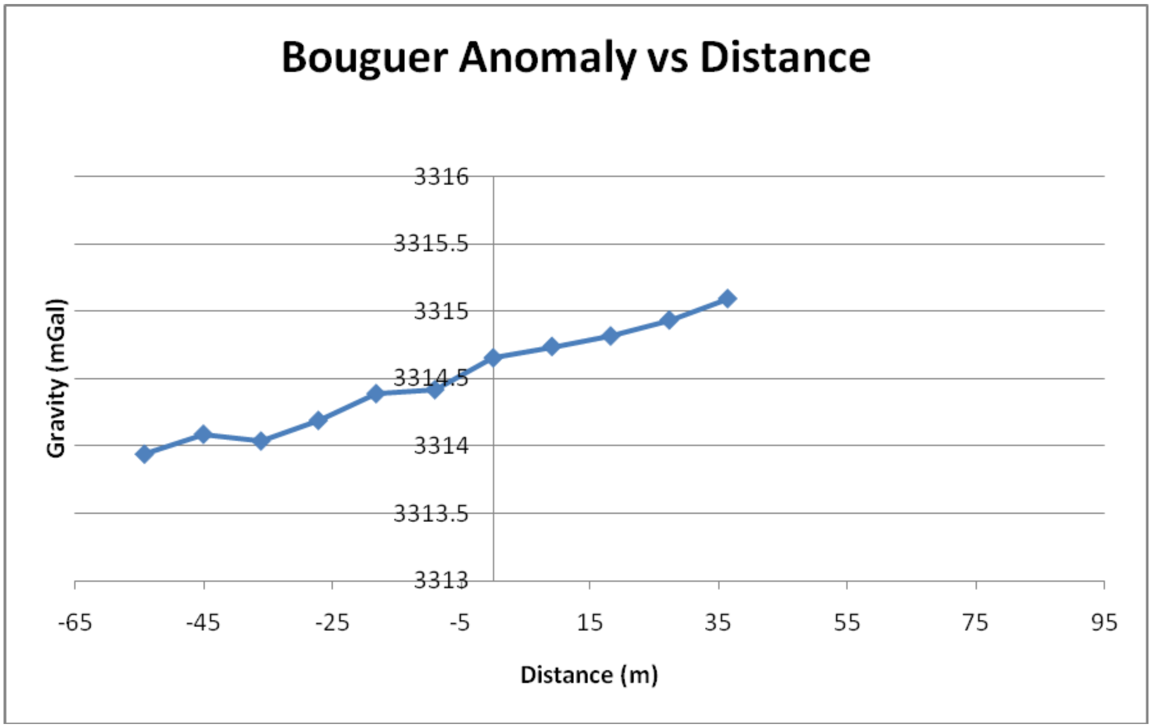
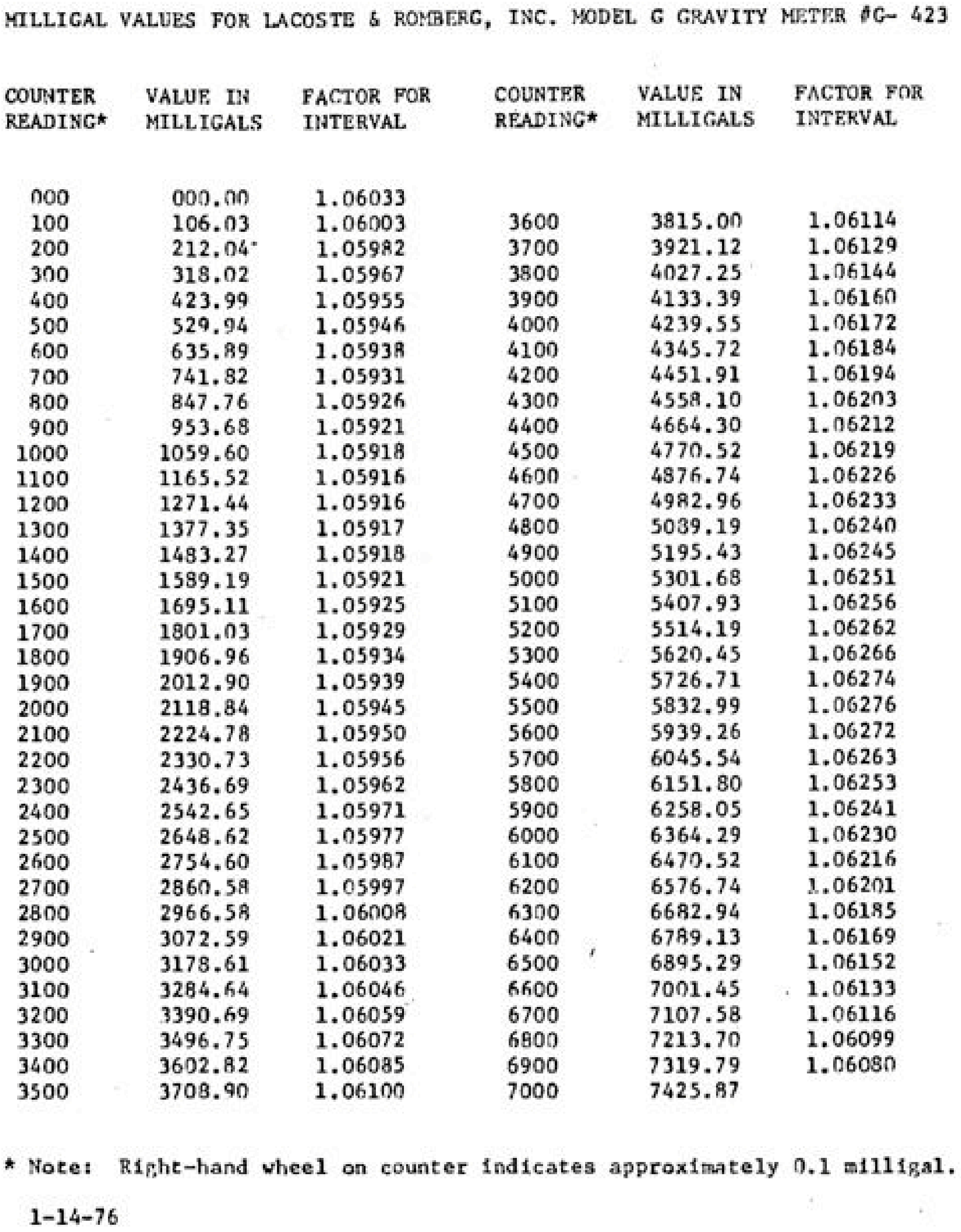


Figure 8: Gravity profile for line 2, extending from SE corner of University Quad to area in front of Career Center

Interpretation and Conclusions

Analyzing the gravity data shows that profiles 1 and 2 in the CalPoly University Quad express a gravity model characteristic of a reverse fault. Both profile 1 and profile 2 exhibit a gradual increase in gravity signal closer to the fault and hanging wall suggesting a signal consistent with the existence of a reverse fault at these locations. The gravity surveys conducted in the University Quad agree with GeoCon Inc’s map of the San Jose fault and with GeoCon’s classification of the San Jose fault as a reverse fault. Profile line 3 in the quad also fits well with a reverse fault profile. Profile 4 at Citrus Lane however, does not exhibit a gravity anomaly expected for a reverse fault (Potter, 2011). The gravity anomaly of the profiles 1-3 is relatively small compared to the USGS Hollywood Fault gravity profile (fig 2) but longer profile lines of up to a few kilometers at Cal Poly Pomona may give a better representation of the total gravity anomaly of the San Jose Fault.

Appendix A: Calibration sheet for LaCoste and Romberg Gravity meter



MILLIGAL VALUES FOR LACOSTE & ROMBERG, INC. MODEL G GRAVITY METER #G- 423

COUNTER READING*	VALUE IN MILLIGALS	FACTOR FOR INTERVAL	COUNTER READING*	VALUE IN MILLIGALS	FACTOR FOR INTERVAL
000	000.00	1.06033			
100	106.03	1.06003	3600	3815.00	1.06114
200	212.04	1.05982	3700	3921.12	1.06129
300	318.02	1.05967	3800	4027.25	1.06144
400	423.99	1.05955	3900	4133.39	1.06160
500	529.94	1.05946	4000	4239.55	1.06172
600	635.89	1.05938	4100	4345.72	1.06184
700	741.82	1.05931	4200	4451.91	1.06194
800	847.76	1.05926	4300	4558.10	1.06203
900	953.68	1.05921	4400	4664.30	1.06212
1000	1059.60	1.05918	4500	4770.52	1.06219
1100	1165.52	1.05916	4600	4876.74	1.06226
1200	1271.44	1.05916	4700	4982.96	1.06233
1300	1377.35	1.05917	4800	5089.19	1.06240
1400	1483.27	1.05918	4900	5195.43	1.06245
1500	1589.19	1.05921	5000	5301.68	1.06251
1600	1695.11	1.05925	5100	5407.93	1.06256
1700	1801.03	1.05929	5200	5514.19	1.06262
1800	1906.96	1.05934	5300	5620.45	1.06266
1900	2012.90	1.05939	5400	5726.71	1.06274
2000	2118.84	1.05945	5500	5832.99	1.06276
2100	2224.78	1.05950	5600	5939.26	1.06272
2200	2330.73	1.05956	5700	6045.54	1.06263
2300	2436.69	1.05962	5800	6151.80	1.06253
2400	2542.65	1.05971	5900	6258.05	1.06241
2500	2648.62	1.05977	6000	6364.29	1.06230
2600	2754.60	1.05987	6100	6470.52	1.06216
2700	2860.58	1.05997	6200	6576.74	1.06201
2800	2966.58	1.06008	6300	6682.94	1.06185
2900	3072.59	1.06021	6400	6789.13	1.06169
3000	3178.61	1.06033	6500	6895.29	1.06152
3100	3284.64	1.06046	6600	7001.45	1.06133
3200	3390.69	1.06059	6700	7107.58	1.06116
3300	3496.75	1.06072	6800	7213.70	1.06099
3400	3602.82	1.06085	6900	7319.79	1.06080
3500	3708.90	1.06100	7000	7425.87	

* Note: Right-hand wheel on counter indicates approximately 0.1 milligal.

1-14-76

Appendix B: Data for Profile 1

Point Name	Distance From Base (m)	Elevation Relative to Base (m)	Gravimeter Reading	Gravity (mGal)	Free-Air Anomaly (mGal)	Bouguer Anomaly (mGal)
Total Station	8.340863265	0.435	na	na	na	na
Base	0	0	3129.42	3315.838733	3315.838733	3315.838733
Base	0	0	3129.42	3315.838733	3315.838733	3315.838733
Base	0	0	3129.39	3315.806919	3315.806919	3315.806919
1	61.34631203	-2.065	3129.95	3316.400777	3315.763518	3315.994701
2	41.83837951	-1.555	3129.16	3315.563014	3315.083141	3315.257228
3	27.76333013	-1.065	3129.23	3315.637246	3315.308587	3315.427817
4	18.29104972	1.035	3129.3	3315.711478	3316.030879	3315.915008
5	47.14498913	2.835	3129.24	3315.64785	3316.522731	3316.205344
6	75.41120606	4.185	3129.175	3315.578921	3316.870412	3316.401888
7	91.9564299	4.195	3129.28	3315.690269	3316.984846	3316.515203

Appendix C: Data for Profile 2

Point Name	Distance from Base (m)	Elevation Relative to Base (m)	Gravimeter Reading	Gravity (mGal)	Free-Air Anomaly (mGal)	Bouguer Anomaly (mGal)
Total Station	-27.6	2.11	na	na	na	na
Base (pt5)	0	0	3128.21	3314.555577	3314.555577	3314.555577
Base (pt5)	0	0	3128.3	3314.651018	3314.651018	3314.651018
Base (pt5)	0	0	3128.27	3314.619204	3314.619204	3314.619204
1	-24.3	1.636	3128.41	3314.767669	3315.272538	3315.089383
2	-18.3	1.152	3128.35	3314.704041	3315.059548	3314.930578
3	-12.1	0.77	3128.31	3314.661623	3314.899245	3314.813041
4	-5.9	0.32	3128.3	3314.672227	3314.770979	3314.735154
5	0	0	3128.3	3314.651018	3314.651018	3314.651018
6	6	-0.282	3128.13	3314.47074	3314.383715	3314.415285
7	12.1	-0.4835	3128.14	3314.481344	3314.332136	3314.386266
8	18	-0.685	3127.99	3314.322275	3314.110884	3314.187572
9	23.5	-1.03	3127.91	3314.237439	3313.919581	3314.034892
10	29.6	-1.37	3128.02	3314.354089	3313.931307	3314.084683
11	36	-1.36	3127.88	3314.205625	3313.785929	3313.938185

Appendix D: Data for Profile 3

Point Name	Elevation Relative to Base (m)	Gravimeter Reading	Drift Corrected Gravity (mGal)	Gravity (mGal)	Free-Air Anomaly (mGal)	Bouguer Anomaly(mGal)
Base	0.132	3128.73	3315.107016	3315.107016	3315.107016	3315.107016
Base	0.132	3128.56	3315.107016	3314.926738	3315.107016	3315.107016
Base	0.132	3128.48	3315.107016	3314.841901	3315.107016	3315.107016
Base	0.132	3128.5	3315.107016	3314.86311	3315.107016	3315.107016
1	-2.128	3127.49	3313.900945	3313.792045	3313.203509	3313.456523
2	-2.247	3127.5	3313.91925	3313.80265	3313.185091	3313.451427
3	-2.285	3127.88	3314.335425	3314.205625	3313.589539	3313.860129
4	-2.198	3127.98	3314.483271	3314.311671	3313.764233	3314.025084
5	-2.319	3127.92	3314.432843	3314.248043	3313.676465	3313.950862
6	-2.232	3128.2	3314.735272	3314.544972	3314.005742	3314.270399
7	-2.134	3128.23	3314.797886	3314.576786	3314.098598	3314.352284
8	-1.393	3128.17	3314.739758	3314.513158	3314.269143	3314.439872
9	-0.69	3128.19	3314.613567	3314.534367	3314.359898	3314.451924
10	-0.531	3128.3	3314.717018	3314.651018	3314.512416	3314.586641
11	-0.414	3128.23	3314.617486	3314.576786	3314.44899	3314.510117
12	-0.23	3128.32	3314.712927	3314.672227	3314.601214	3314.641741
13	-0.026	3128.46	3314.845992	3314.820692	3314.797233	3314.814921
14	0.132	3128.45	3315.107016	3314.810087	3315.107016	3315.107016
16	0.407	3128.58	3315.209747	3314.947947	3315.294612	3315.263825
17	0.873	3128.53	3315.165524	3314.894924	3315.394196	3315.311239
18	1.42	3128.59	3315.247851	3314.958551	3315.645328	3315.501133
19	1.861	3128.6	3315.265056	3314.969156	3315.798625	3315.605058
20	2.104	3128.62	3315.299465	3314.990365	3315.908024	3315.687253

Appendix E: Data for Profile 4

Point Name	Distance from Base (m)	Elevation Relative to Base (m)	Gravimeter Reading	Gravity (mGal)	Free Air Anomaly (mGal)	Bouguer Anomaly (mGal)
Base (pt 9)	0	0	3131.65	3318.203559	3318.203559	3318.203559
1	-60.97029685	-0.456	na	na	na	na
2	-53.33103804	-0.424	3131.96	3318.532302	3318.401455	3318.448923
3	-45.71743101	-0.422	3131.8	3318.362628	3318.232399	3318.279643
4	-38.10418058	-0.403	3131.9	3318.468674	3318.344308	3318.389425
5	-30.49489441	-0.397	3131.86	3318.426256	3318.303741	3318.348187
6	-22.83999969	-0.379	3131.8	3318.362628	3318.245669	3318.288099
7	-15.22893775	-0.338	3131.81	3318.373233	3318.268926	3318.306766
8	-7.611927088	-0.176	3131.73	3318.288396	3318.234082	3318.253786
9	0	0	3131.65	3318.203559	3318.203559	3318.203559
10	7.648145723	0.249	3131.48	3318.023281	3318.100122	3318.072246
11	15.25880929	0.49	3131.53	3318.076304	3318.227518	3318.172661
12	22.89002831	0.755	3131.46	3318.002072	3318.235065	3318.15054
13	30.48353728	1.065	3131.4	3317.938444	3318.267103	3318.147873
14	38.12677313	1.386	3131.34	3317.874816	3318.302536	3318.147369
15	45.73060206	1.649	3131.31	3317.843003	3318.351884	3318.167273
16	53.33707095	1.981	3131.2	3317.726352	3318.337689	3318.11591
17	60.94566252	2.389	3131.16	3317.683934	3318.421179	3318.153723

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